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ARE U.S. WEAPONS PRODUCERS DEPENDENT ON JAPANESE AND OTHER FOREIGN SUPPLIERS?

SUMMARY

The increasing globalization of the American economy, the diffusion of technological capabilities and the Pentagon's declining budget have focused attention on the U.S. defense industry's vulnerability to foreign suppliers. The distinction betwecn dependency and vulnerability develops when the loss of a foreign source would have a serious negative effect on national security. For most foreign-supplied items vulnerability is only a remote possibility because of the existence of alternative sources. Nevertheless, the use of foreign inputs in military equipment is increasing to the levels seen in commercial production, particularly in the lower tiers of the industry's supply chain and mainly for the economic reasons of cost and quality. Japanese firms and products do not dominate foreign defense supplies except for some electronics components and optical items.

The fear of politically motivated cutoffs or other kinds of inaccessibility to needed parts and advanced technologies, especially from Japan, has stimulated several studies of the problem. Adopting policies to increase and disperse the number of sources is usually the best approach to dealing with potential vulnerabilities. Stockpiles can be used when the supply is concentrated in a single firm or country. Other policies include defense of supply lines, pressures to counter political cutoffs, substitution of alternative materials or components and the redesign of systems. The benefits from foreign sources of supply include lower costs, higher quality, speedier delivery and more advanced technologies than might be available from American sources. The policy problem is to balance the benefits of dependency against the risks of vulnerability and to mitigate the risks through policies that minimize the costs of insuring against uncertain future events.

The Globalization of Supply

As far back as 1790 Congress showed concern about the new republic's dependence on foreign suppliers for manufactured goods, particularly "for military and other essential supplies."[1] Responding to a request on this matter from Congress, Secretary of the Treasury Alexander Hamilton in 1791 proposed policies to stimulate the broad development of manufactures. (Indeed, Mr. Hamilton gave little consideration to military supplies in his arguments for the importance of manufacturing but rather used the "national security" rationale provided by Congress to promulgate a broader policy.) Despite the early concern, the United States was to remain in a dependent position for much of its military technology until 1945.

At the end of World War II the United States for the first time became preeminent in military process and product technologies. Yet, at the same time, when American leaders helped to initiate new policies aimed at developing and integrating the world economy, they planted the seeds for the very globalization that eventually would undermine U.S. defense autarky. Since 1945 the United States gradually has become a more active participant in the global economic system. Imports, which were only 6.1 percent of gross national product as recently as 1960, now account for 11 percent of the national product. In manufacturing the foreign share is greater; nonpetroleum merchandise imports make up 20 percent of the "goods" sector of GNP. Despite the historical desire for defense industrial independence, the growing globalization of U.S. economic activity has had an inevitable effect on American weapons autarky. Defense planners gradually have come to sense a level of dependence and vulnerability to foreign suppliers not experienced since the 1930s.

The perception of vulnerability to foreign companies and nations has been abetted by several other recent trends: international economic development, falling defense budgets and the loss of U.S. dominance of many defense technologies. Worldwide economic development has been accompanied by a general diffusion of technical competence and industrial expertise. Specialized producers of hundreds of products now can be found in a score of countries in Europe, Asia and elsewhere. War planning, which had accommodated the geographic concentration of familiar materials like chromium or tungsten, now must focus on less familiar minerals, materials and products in less familiar places.

Since most foreign products are chosen for reasons of economic efficiency, the military in the past could buy itself out of dependency by simply paying higher prices for U.S.-made products. Declining U.S. defense budgets, however, are placing a greater premium today on reducing costs just at the time that a greater variety of high-quality, low-cost foreign supplies are becoming more available.

Electronics, computing, communications and new engineering materials are examples of technologies in which the military occupied the frontiers between the 1940s and the 1980s. Recently, however, that dominance has been lost as commercial demands not only have surpassed the defense market in size but also have called for higher levels of performance. The arcane technologies and black arts of weapons production now are becoming banalized. As commercial research and development and production of high-end products have arisen abroad, sourcing of military components often has been shifted to these new suppliers.

In short, the peculiar period of U.S. independence in defense technological and industrial affairs prevailing since 1945 is drawing to a close. Closely tied to this loss of independence has been the rise of Japan as a leading exporter to the United States and a key source of many defense electronics components. Japanese technical competence is demonstrated by, among other things, the scale and the quality of Japanese corporate patents in the United States. From 1985 to 1989 Japanese

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companies were granted as many as two-thirds the number of U.S. patents as American companies. One could dismiss these figures as simply reflecting the well-known Japanese propensity to patent every possible finding; however, the average quality of these patents as measured by examiner citations is higher than comparable American patents.[2] In the top 1 percent of highly cited patents issued from 1975 to 1981 Japanese-held U.S. patents were proportionately overrepresented in automotive, electronics, photographic and photocopying technologies — with electronics showing the most rapid growth. The issue of dependence on Japanese technology, though, is both broader and narrower than Japan, or Japanese electronics, or even Japanese-sourced ceramic packages for integrated circuits. Since the sense of growing dependence is only recent, much of the discussion to date has been hampered by weak logic and poor data. Fortunately, several good studies have emerged that clarify the policy problems and that investigate the quantitative nature of dependency.

Three questions are central to a better understanding of the apparently growing dependence of U.S. defense production on foreign sources:

- What are the policy concerns?
- What are the dimensions of the actual use of foreign inputs?
- What policies could mitigate the problems?

What Is the Problem?

Most analysts differentiate between "dependence" and "vulnerability." Dependence in a military equipment context simply means that an input comes from a foreign source. Dependency becomes vulnerability when the loss of this foreign source would have a significant negative effect on U.S. national security by precluding the production of a critical military system or resulting in less system capability.[3]

Before jumping into the subject of vulnerability, it is useful to recognize that global access to technologies, products and skills is an asset as well as a potential problem. On the plus side a larger, more diverse pool than is available only within the United States confers many advantages. Dispersion of sources reduces the risks from disruptions occurring in a specific region or country. Overseas sources may be closer to where items may be used in warfare. A multiplicity of sources increases the likelihood of more favorable costs, quality or technology than if supply were confined only to the United States. The presence of many international market participants enhances the level of competition, with probable payoffs in future costs and technological developments. Indeed, prior to and during World War II, this nation acquired important military technologies from abroad, including radar and jet engines. Dependency, by and large, confers advantage.

Vulnerability is the problem that warrants attention. The analytical issue is to devise policies that reduce the risks from global interdependence and its potential vulnerabilities while not forsaking the benefits. The notion of vulnerability cannot be separated from time scales and scenarios. For example, a desperate need for spare parts in a high-intensity war with lines of communication under attack conveys quite a different perception of vulnerability than peacetime defense production. The policies that deal with one set of contingencies, therefore, may be irrelevant to another. The urgency of supply is closely tied to scenarios of use. Today's likely scenarios include peacetime, small-scale conflicts (Grenada), short, intense wars (Iraq), and more prolonged wars on less than a global or continental scale (Vietnam and Korea). Omitted from this list are the World War II and U.S.-Soviet types of conflicts that dominated mobilization plans for decades.

Supply disruptions can result from many different causes. Armed destruction of supply lines is the classical military disruption; submarine attacks on shipping is an example of such an action. Natural disasters, local political instability, economic collusion, terrorism, labor strikes, regional conflict and economic instability are among the other causes of disruptions that have occurred. In a

national emergency or for specifically designated defense systems the Defense Production Act can compel delivery from U.S.-based firms, but it cannot overrule the effects of tornadoes, earthquakes, terrorism or bankruptcy. For many of these possible sources of problems the probability of disruption is not necessarily greater from a foreign source than from an American supplier.

Politically motivated cutoffs of supply recently have come under closer scrutiny. "The contemporary movement toward globalization opens the door in peacetime to foreign influence, foreign control, and foreign domination," wrote Theodore Moran in a 1990 article on the expanding supply line of U.S. defense producers.[4] Perhaps this view has such a currency among American analysts because the United States has been the chief user of supply cutoff as a foreign policy tool; this use naturally leads to a fear of similar behavior by others. The United States has withheld computers and technology from France to retard its strategic missile developments, a policy later reversed; threatened to cut off oil supplies to Great Britain and France during the Suez crisis; and denied arms sales to the Middle East for foreign policy reasons. The U.S. government has attempted to influence the subsidiaries of American firms in Europe to promote Washington's policies toward China, the Soviet Union and the Middle East. European experience demonstrates a real threat of interference, even from close allies. The United States itself was the victim in 1973 of a petroleum embargo by the Organization of Petroleum Exporting Countries; for the following decade such a possibility figured prominently in anxieties about other strategic imports.

Concern over a different kind of U.S. vulnerability has arisen in recent years as Japan has grown in importance as a supplier of advanced electronics components, electronics production and test equipment, and machine tools. Coupled with this new fear that another country will develop leading-edge technologies and achieve the production capabilities to turn out militarily critical products is the worry that the United States will have insufficient access in either war or peace to advanced equipment and products and thus be prevented from developing and producing the best military systems possible. In addition, lack of access could affect adversely the Pentagon as buyer and the defense industry as supplier by reducing their astuteness and competence in the conceptual development of new systems. Designers and engineers often point out that frequent iterations and feedback are necessary in producing the designs of new systems and figuring out the various trade-offs. Geographical proximity, common language and shared national interests, it is alleged, can help overcome the organizational and the commercial barriers that retard such interchange.

Disruptions of supply or poor access to a product or process technology translate into vulnerability only if they cause a significant loss of military capabilities. Many items are not critical because they perform only a peripheral role or have many substitutes. Cloth and leather for uniforms and boots are examples. Other items may be essential for some scenarios but not for others. For example, during the conflict in Iraq production was not contemplated for major platforms such as the F-16 aircraft, but worrying shortages developed for electronics spare parts for the F-16 radar. A larger and longer conflict could have transformed F-16 production dependencies into a vulnerability. Multiple sources, whether different companies or countries, reduce the criticality of any one source. Over the longer run substitutability among materials, parts, subsystems and entire systems can reduce potential vulnerabilities.

The possibility of politically instigated supply disruptions depends on the state of political relations with the supplying nation. America's most common sources of foreign products are countries with which it has the closest political ties. In fact, most military analysts consider Canadian sources to be equivalent in reliability to U.S. suppliers. Great Britain, Germany and Japan possess higher vulnerability rankings only because of their greater distance from the United States. One report evaluates the access to technology from close allies as a major asset but acknowledges the potential for somewhat greater risk than from domestic sources.[5] Regardless of the level of friendliness, however, there is always greater political risk associated with foreign suppliers than domestic sources.

The likelihood of a problem developing from dependence and vulnerability depends on the probability of a cutoff that could leave the U.S. defense establishment with a significant loss of capability. The probability of loss increases with the concentration of sources, the difficulty of substitution, the antagonism of the originating country, the criticality or essential nature of the item, the urgency of its need, and the distance from the user. For leading-edge technologies long-run vulnerability may arise if access is difficult.

Measures of Dependency

U.S. thinking about defense dependency on foreign supplies has progressed from an impressionistic level relying on anecdotal evidence, to a stage of structured but partial studies examining the first few tiers of supply, and finally to a more thorough understanding based on investigations probing four levels of supplier relationships. The most detailed study to date was performed by the Department of Commerce's Office of Industrial Resource Administration for the U.S. Navy.[6] This study made use of Commerce's mandatory data collection authority under the Defense Production Act to conduct a complete assessment of the subcontractor supply chain for three Navy systems: the high-speed, antiradiation, air-to-surface missile (HARM); the Mark-48 ADCAP (advanced capabilities) torpedo; and the Verdin submarine communications system. These systems were chosen as representative of the broad range of Navy systems and technologies.

The prime contractors and the major subsystem subcontractors (first-tier suppliers) were asked to identify each of the 1988 domestic and foreign sources (second tier) from which they purchased products or services in support of the particular weapons system. The domestic firms identified in this survey were sent questionnaires seeking information on their suppliers (third tier), and so on through the next tier. The overall response rate was 63 percent. By the time of the survey some of the identified firms had gone out of business; others had been mistakenly identified. The adjusted response rate was closer to 80 percent.

One of the striking findings of the Commerce study is the large number of firms contributing to defense production. For just a single system, the HARM missile, more than 4,000 firms were identified as fourth-tier suppliers. Overall, the study elicited responses on 11,638 active subcontractors in the United States and 1,043 abroad, including multiple mentions of the same companies. After taking account of this duplication participant numbers drop to 6,747 domestic firms and 327 foreign; at least 28 of the foreign suppliers were American-owned. Table 1 presents the number of foreign and domestic firms by system and supply level; the listings include multiple citations of some companies. The number and the proportion of foreign participation climb sharply at lower levels of the supply chain. The study found no foreign firms in the top group of contractors but 12.1 percent in the lowest group. The pattern across systems suggests greater rates of foreign activity for the more electronically oriented systems like the Verdin.

Counts of the number of firms, however, give little sense of the products supplied by foreign manufacturers, their value or how essential they are. Table 2 gives an account of the number of separate items coming from the leading countries for all three systems. Again, the volume of foreign contributions increases markedly at lower tiers. The number of countries involved rises strikingly from just three in the second tier to 39 in the fourth tier. Also, Japanese firms increase in importance at the lower levels. Japanese parts do not show up at all as direct inputs to the prime and the major subsystem contractors; however, Japan is the leading foreign supplier to third-tier producers.

By dollar value foreign contributions vary greatly across weapons systems and supplier tiers (see Table 3). Foreign purchases accounted for almost 40 percent of the total for the Verdin system's second-tier contractors but only 4.7 percent for the HARM missile. Japanese companies were the main suppliers to second-tier producers for all three systems, but their position varied at the next lower tier. According to this evidence, Japan is an important supplier to America's defense industry, but that nation does not dominate quantitatively along the various dimensions examined above.

Table 1: **Number of Identified Firms by Supplier Tier and Weapons System, 1988**

	Tier 1		Tier 2		Tier 3		Tier 4	
	Total	Foreign	Total	Foreign	Total	Foreign	Total	Foreign
HARM	6	0	765	13	1,904	106	4,149	593
MK-48	5	0	211	1	1,065	11	2,060	156
Verdin	2	0	193	1	425	52	866	110
Total	13	0	1,169	15	3,394	169	7,075	859

Source: Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the Domestic and Foreign Subcontractor Base: A Study of Three U.S. Navy Weapon Systems* (Washington, D.C.: March 1992), Table 1, p. 16.

Table 2: **Number of Foreign-Sourced Items by Leading Country for Three Weapons Systems, 1988**

Prime Contractors from Tier 2

Number of Countries	3
Total Items	10
United Kingdom	5
Canada	4
Germany	1

Tier 2 from Tier 3

Number of Countries	22
Total Items	108
Germany	20
Japan	20
Canada	10
United Kingdom	10
France	9

Tier 3 from Tier 4

Number of Countries	39
Total Items	186
Japan	56
Canada	27
Germany	25
Taiwan	14
Sweden	13

Source: Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the Domestic and Foreign Subcontractor Base: A Study of Three U.S. Navy Weapon Systems* (Washington, D.C.: March 1992), Tables 19-21, pp. 53-56.

The great surge in foreign direct investment in the United States in the 1980s generated concern among defense planners that foreign ownership of defense contractors could be a potential problem. Commerce analysts were able to segregate such firms in their sample. Defense-related shipments for the three examined systems by foreign-owned domestic facilities comprised 2.32 percent of system shipments by the firms included in the survey (see Table 4). British-owned companies accounted for more than half of the foreign share. Japanese-affiliated company shipments came to only 0.5 percent. Neither foreign-owned firms in general nor Japanese companies in particular are major players in the American defense market.

Table 3: **Foreign Purchases by Weapons System, Leading Country and Supplier Tier, 1988**

HARM Missile

Tier 2		Tier 3	
Percent Foreign	4.7%	Percent Foreign	17.6%
Total Foreign	$60 million	Total Foreign	$582 million
Japan	23	Canada	355
United Kingdom	8	United Kingdom	50
Germany	8	Japan	47
Switzerland	5	South Africa	32
France	5	France	23

MK-48 Torpedo

Tier 2		Tier 3	
Percent Foreign	5.3%	Percent Foreign	5.1%
Total Foreign	$8.5 million	Total Foreign	$69 million
Japan	6.5	Japan	11
United Kingdom	2.0	Netherlands	9
		China	8
		Germany	7
		Taiwan	5

Verdin Communications System

Tier 2		Tier 3	
Percent Foreign	39.8%	Percent Foreign	8.8%
Total Foreign	$100 million	Total Foreign	$28 million
Japan	70	Taiwan	10
Italy	17	Switzerland	7
Germany	6	Germany	5
Thailand	5	Japan	2
Mexico	3	Finland	2

Source: Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the Domestic and Foreign Subcontractor Base: A Study of Three U.S. Navy Weapon Systems* (Washington, D.C.: March 1992), Tables 10-12, pp. 33-35.

A question that comes up frequently in nondefense as well as defense circles is whether foreign-owned firms in the United States tend to purchase more of their inputs from abroad than do companies owned by domestic interests. Evidence from the defense subcontractor base suggests a mixed answer. Foreign-owned second-tier firms purchase about the same proportion of their inputs from foreign sources as domestic firms (see Table 5). Third-tier firms, in general, look more to foreign sources; the foreign-owned group engages in 40 percent more foreign buying than their domestically owned counterparts.

A qualitative evaluation of the dependency information is necessary to determine whether foreign sourcing is a potential problem. With respect to foreign-owned U.S. firms, Commerce's review of the products produced by these firms indicated that similar capabilities existed among U.S.-based producers. Furthermore, current U.S. law enables the president to require defense deliveries from a domestic facility on a preferential basis, regardless of ownership. Despite the tendency of foreign-owned firms to import more from abroad, they do not appear to represent a vulnerability — mainly because of the existence of other sources.

Table 4: **Defense Shipments of Foreign-Owned U.S. Facilities for Three Weapons Systems, 1988**

Country of Ownership	Defense Shipments (millions of dollars)	Share of All Defense Shipments
United Kingdom	$149.7	1.30%
Japan	53.7	0.47
France	33.4	0.29
Germany	14.6	0.13
Hong Kong	4.0	0.03
Foreign Total	267.1	2.32

Source: Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the Domestic and Foreign Subcontractor Base: A Study of Three U.S. Navy Weapon Systems* (Washington, D.C.: March 1992), Table 7, p. 29.

Table 5: **Foreign Purchases for Three Weapons Systems by Domestic and Foreign-Owned Suppliers (1988)**

(share of total purchases)

	Ownership	
Supplier Tier	Domestic	Foreign
Tier 2	6.5%	6.9%*
Tier 3	13.7	19.6

*One outlier removed.

Source: Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the Domestic and Foreign Subcontractor Base: A Study of Three U.S. Navy Weapon Systems* (Washington, D.C.: March 1992), Table 8, p. 30.

When Commerce asked suppliers for the reason they bought foreign-made items, one of the most numerous responses (239) was higher quality; 169 mentioned lower price. Of the respondents that purchased raw or processed materials from overseas, 242 said that the United States had no economically viable mining capacity. Respondents named 17 different materials in this category, but 95 percent of the value was concentrated in only nickel, ferrochrome and tantalum. Strategic stockpiles, the traditional solution to the problem of dependency on bulky materials, exist for these items and for most others with single-country suppliers. For other materials sufficient dispersion of sources appears to reduce the vulnerability potential. A large share of foreign dependency, therefore, was stimulated by economic motivation. For materials not available domestically, strategic stockpiles or multiple sources minimize the anxieties over dependence.

The sanguine situation described above, though, does not extend to every part and material examined. A few cases stand out. For example, over 82 percent of the ceramic packaging for semiconductors came from Japan — most from a single company. Ironically, although domestic companies made ceramic packaging, most users were unaware of the local supplies. Nevertheless, this product represents a potential vulnerability because of lower domestic quality and a tendency to concentrate on a single source.

Another common dependency problem lies in needle-bearing wire rod; defense contractors contend no U.S. sources manufacture rod of the required high quality. Sourcing was scattered among eight firms in three countries, with 80 percent coming from six Japanese firms. The importance of this product lies in its use in precision bearings, which are critical components in many military systems. Thus, the relative concentration of wire rod capabilities abroad creates a potential vulnerability.

Another concern is that some stockpiled materials are of insufficient quality for current high technology needs. Therefore, even though the quantities appear to be sufficient for emergency use, they could fail to meet production requirements.

Among other studies that have examined dependency on foreign suppliers is one by the Institution for National Strategic Studies of the National Defense University, which examined the foreign sources of 17 precision-guided munitions, including air, sea and ground-based missiles, a torpedo, a bomb and an artillery round.[7] The main sources of information were 500 companies identified as suppliers of at least one major PGM part; these companies were asked to list their foreign suppliers. The authors estimated that their 60 percent response rate covered about 80 percent of the value of the sample of PGMs under investigation. This survey method would have covered roughly the second and third tiers of suppliers. The foreign parts that were identified were further classified into two groups: those related to integrated circuits and everything else.

The survey response of almost 300 subcontractors revealed 27 instances of foreign dependency. Among this group were foreign suppliers of parts for eight high-cost subsystems, shown in Table 6. U.S. sources had the capability to produce parts for seven of the eight subsystems and indicated that domestic supplies could replace the foreign components with a two- to three-month lead time under wartime conditions.[8]

The study's authors defined two other subclasses of foreign parts: low- and high-incidence subcomponents used in one and more than one system, respectively (see Table 7). Seven of these 14 components came from Germany and three from Japan; the Japanese components included precision optics and two types of field-effect transistors for use in high-frequency radars. American plants claimed to be able to produce the FETs with a one-year lag; the optics were sourced from Germany as well as Japan, with a U.S. company as an alternative. Alternative providers for certain types of complex ferrite cores and high-purity silicon were not easily identified, the study noted. Otherwise, no great difficulties were foreseen in finding existing domestic producers or in getting a new producer on-line within a year.

Integrated circuits presented a more complex story. The extent of the defense industry's foreign dependence was so broad that the researchers estimated that a cutoff would hurt production severely.[9] Military contractors rely on overseas facilities for assembly of domestically produced chips, a large percentage of silicon wafers, most of their ceramic packages, metal parts for nonceramic packages and the raw glass to make glass masks. In assessing vulnerability the analysts noted that production of all the currently dependent items could be undertaken in the United States, perhaps at a cost disadvantage, with sufficient lead time. However, because of the pervasiveness of foreign IC suppliers and because of the trend toward even greater foreign sourcing in 1987 when the study was written, the researchers warned against complacency in not addressing potential future problems. Their preferred solution to vulnerability was the use of stockpiles in the form of larger active inventories.

Table 6: **High-Cost Precision-Guided Missile Subsystems from Foreign Sources, 1985**

Program	Item	Country
Stinger	Launch tube	Israel
Harpoon	Extrusions	Australia
HARM	Actuator	United Kingdom
HARM	Gear motor	United Kingdom
Standard	Castings	Israel
Harpoon	Rocket motor case	United Kingdom, Australia
Skipper	Rocket motor case	United Kingdom
HARM	Rocket motor case	United Kingdom

Source: Martin Libicki, Jack Nunn and Bill Taylor, *U.S. Industrial Base Dependence/Vulnerability; Phase 2 — Analysis* (Washington, D.C.: National Defense University, November 1987), p. 118.

Table 7: **Low- and High-Incidence Precision-Guided Missile Subcomponents from Foreign Sources (1985)**

Item	Source	Incidence
Ball Screws	United Kingdom	Low
Copper Liner Forms	Switzerland	Low
Bearings	Germany, other	Low
Molybdenum Foil	Austria	Low
Printed Wiring Board Plating Bath	United Kingdom	Low
Springs, Pivots	Germany, South Africa	Low
Radome Chemicals	Germany, Mexico	Low
Silicon Field-Effect Transistors	Japan	High
Gallium Arsenide Field-Effect Transistors	Japan	High
Ferrite Cores	Germany	High
Precision Optics	Germany, Japan	High
Sapphire	Switzerland	High
Butane Triol	Germany	High
High-Purity Silicon	Germany	High

Source: Martin Libicki, Jack Nunn and Bill Taylor, *U.S. Industrial Base Dependence/Vulnerability; Phase 2 — Analysis* (Washington, D.C.: National Defense University, November 1987), pp. 120 and 126.

A 1990 study by the Institute for Defense Analyses arrived at conclusions that were quite close to the National Defense University report described above. IDA looked at the display components in aircraft cockpits (the AV-8B, the F-18 and the P-7 aircraft), the microelectronics of two generations of aircraft radar (the APG-66 and the APG-68 on the F-16), the subsystems on two missiles (the AIM-7 Sparrow and the AIM-120 AMRAAM or Advanced Medium-Range Air-to-Air Missile), and large combat vehicle engines.[10] Although the survey of the supply chain was neither as systematic nor as thorough as the studies reviewed above, the findings and the conclusions had the same tone.

> The study found no case in which foreign technology sourcing appears to threaten imminent risk of supply disruption. However, it did find several technologies now heavily dependent on foreign sources in which reconstitution of U.S. production capabilities could face delays of several years ... .[11]

Among the components cited as being at greatest risk of such disruption were microelectronic devices, ceramic packages, silicon, gallium arsenide, ferrite coils and filter glass. All of these items also were identified in the other studies. Production equipment deficiencies showed up in certain high-precision numerically controlled machine tools and semiconductor manufacturing equipment, now sourced mainly from Japan. The radar evaluation noted that 99 percent of the ceramic bases for integrated circuits were imported, with almost as high proportions for the lead frames and covers.

IDA analysts also expressed concern about high-resolution display technologies, but these worries mainly reflected projected future trends. Most current aircraft cockpit displays rely on cathode-ray tubes. Flat-panel displays are only slowly replacing CRTs because of the high cost of the new technology and technical problems that have yet to be resolved over extreme brightness in the cockpit environment. Foreign components in the examined CRT displays are shown in Table 8. The most significant foreign dependency problems are associated with optical filters, filter glass and molded ferrites. Each of these products come from a single Japanese company. Moreover, several years would be required before alternative domestic supplies could be made available. The evaluation of flat-panel displays noted the relatively weak and undeveloped state of domestic technologies for defense systems.[12]

Analysis of the Sparrow and AMRAAM missiles revealed little use of foreign parts and components at the first and second tiers. At lower tiers the chief offshore supplies consisted of microelectronic components, especially ceramic packages and gallium arsenide substrates. Missile foreign dependencies are shown in Table 9. The AMRAAM missile incorporates more recent technology than the latest Sparrow model. Electronics dominates the AMRAAM design, primarily in the guidance section — which comprises 77 percent of the weapon's cost. Only 2 percent of the cost is embodied in the armament, 3 percent in the airframe, 5 percent in propulsion and 8 percent in the control section. (Five percent of the missile cost is incurred in the assembly process.) Because of the importance of its electronics, the AMRAAM is more heavily dependent on foreign sources than the older Sparrow.[13] Except for the familiar microelectronic components, procurement was driven offshore mainly by costs. The United States was estimated to have the capability to produce the items but with varying delays. Materials dependence could be met by stockpiles, the IDA report said.

IDA's examination of tank engine sourcing revealed no foreign components in the AGT-1500 turbine engine on the M-1 tank. Two new engines were competing for the U.S. Army's advanced engine program. One of these, the LV100, was designed jointly by General Electric Co. in the United States and Motoren-und-Turbinen Union in Germany. The LV100 has three subsystems developed and currently manufactured in Germany. However, during production GE contractually is required to use American-built parts. The other advanced engine is Cummins Engine Co.'s XAV28. Its foreign components include a fuel injector solenoid built in Japan and head bolts from Germany. The solenoid contract was given to a Japanese firm when the U.S. bidder required $750,000 for development tooling. The Japanese bidder agreed to redesign a commercial product at no cost to the

Table 8: **Foreign Cathode-Ray-Tube Cockpit Display Parts**

Aircraft	Item	Source	Reason for Foreign Sourcing	Delay for Alternate Source
F-18	Filter glass and filter	Japan	Only source	5-6 years
F-18, AV8B	Molded ferrites	Japan	Size of buy; part complexity	4-5 years
F-18, AV8B	Glass bulb for CRT	Japan, Germany	Quality; few sources	1 year+
F-18, AV8B	Electronic cards	United Kingdom, United States	Cost	6 months-
F-18	Chassis casting	Canada	Offset agreement	6 months+
F-18, AV8B	CRT enhancement filter	Germany	Quality not available domestically	1 year+
F-18, AV8B	Miscellaneous display components	United Kingdom	Unique components	1 year+
F-18, AV8B	Test equipment	United Kingdom	Cost	3 years+
P-7	Phosphors	Japan	Quality not available domestically	1 year
P-7	Glass funnel	Germany	Quality; few sources	1 year+
P-7	Glass faceplates	Germany	Quality; few sources	1 year+
P-7	Color display	Japan	Quality; cost	1 year+

Source: Erland H. Heginbotham *et al., Dependence of U.S. Defense Systems on Foreign Technologies* (Alexandria, Virginia: Institute for Defense Analyses, December 1990), p. 16.

Table 9: **Foreign Missile Parts**

Missile Type and Sector	Item	Source	Reason for Foreign Sourcing	Delay for Alternate Source
AMRAAM guidance	Magnesite for radome	Mexico	Only source	Indefinite
AMRAAM guidance	FETs and capacitors	Japan	Cost	n.a.
AMRAAM guidance	Ceramic chip carriers	Japan	No domestic supplier	Indefinite
AMRAAM guidance	Hybrid circuit components	Asia, Europe	Cost	6 months
AMRAAM guidance	Gallium arsenide	Japan	No domestic supplier	1 year+
AMRAAM guidance	Actuator motor	United Kingdom, United States	Cost	None
AMRAAM warhead	Titanium	Australia	No economic U.S. source	n.a.
AMRAAM warhead	Chromium	South Africa	No U.S. source	Indefinite
AMRAAM rocket motor	Propellant chemical (IPDI)	Germany	EPA regulations	Short
AMRAAM rocket motor	Flow-form machine	Germany	Cost	1 year-
Sparrow rocket motor	Propellant chemical	Germany	n.a.	n.a.
Sparrow rocket motor	Flow-form machine	Germany	Cost	1 year-

Source: Erland H. Heginbotham *et al., Dependence of U.S. Defense Systems on Foreign Technologies* (Alexandria, Virginia: Institute for Defense Analyses, December 1990), p. 23.

Army. In the case of the head bolts, foreign supply of the set of 40 required for each engine represented a savings of $3,000 per engine.[14]

Policy Implications: Reducing Vulnerabilities

The evidence on foreign inputs going into U.S. weapons systems shows that foreign dependency seems to be growing, that most offshore sourcing arises from commercial decisions based on cost and quality considerations, and that a limited number of components represent unique foreign manufacturing or technological capabilities. Especially at the lower supply tiers, most of the pieces, parts and supplies are the ordinary stuff of production. Many of the domestic companies, when surveyed, were unaware that their shipments were to be used in military systems.[15] Foreign supplies destined for defense products follow this same pattern: at the lower tiers most imported parts are just "stuff."

The pattern of defense-related foreign inputs follows the general structure of American merchandise imports. America's leading overall import sources are Canada, Japan, Mexico, Germany, Taiwan, and the United Kingdom. Except for Mexico, these are the same countries that dominate the defense supply list. America's main allies in the North Atlantic Treaty Organization -- Canada, Germany and the United Kingdom -- are the chief suppliers of specifically military items: rocket motor cases and aircraft ejection seats, for example. However, they, and the other supplying countries including Japan, mainly export broader classes of industrial goods. For most such goods the familiar notion of "dual use" loses much of its meaning. Whether it is copper foil or bearing wire, or any of several hundred other items, these are not dual-use but multiple-use products.

The appropriate focus of policy is, thus, on a small number of key items and materials that subsequently find their way into many weapons. These often come from a limited number of sources, perhaps a single country and sometimes a single company. When coupled with the absence of alternative sources, this situation yields the raw material for vulnerability.

Policies can eliminate or mitigate the potential costs of disruption or lack of access. Taken as a whole, such policies are a form of insurance against uncertain, harmful events. But insurance is rarely free. An investment in insurance attempts to shift resources from a period of calm to a future occasion of disruption when the items in questionable supply would have a highly time-urgent value. Decisions to invest in insurance depend on expectations about the type, magnitude, timing, duration, frequency and, especially, the cost of the future disruption. The analytical policy problem is to balance the cost of insurance with the benefits that the insurance is expected to provide by reducing or compensating for the possible losses.[16]

Policies to insure against foreign supply vulnerabilities can take many forms: military defense of supply lines; alternative transport routes and modes; economic, political or military pressures to counter politically motivated cutoffs; dispersion of sources of supply; creation of new sources; substitution of alternative materials, parts or even entire systems; redesign around critical items; and stockpiles. One policy that often is recommended as a solution to a perceived foreign dependency problem -- domestic production -- may be too narrowly conceived. As Georgetown University's Theodore Moran points out, the promotion of a national champion that is less than successful can lead to a nightmare for defense industrial strategists in "... being tied to a product of such high price, long delays, and inferior technological performance that the user finds his own security compromised."[17]

Mr. Moran's policy advice focuses on eliminating concentrations of supply. "Diversification and multiplication of the companies and locales upon which a nation can draw offers the most dependable method for minimizing the threat of foreign control."[18] He goes on to say, "The real test for whether a threat to national security exists is not whether a subsector of a particular industry appears headed for extinction on American soil, but whether the emerging array of suppliers is so concentrated that it offers the potential for foreign political interference."[19] Concentration obviously

raises the probability for all types of disruption. Mr. Moran proposes a "4/50" rule of thumb to assess the degree of concentration. To avoid political interference no four countries should supply more than 50 percent of the arm's-length world market; to avoid restrictive behavior by corporations no four firms should control more than 50 percent of the market. Concentration measures that violate this threshold are a signal for further action. While the specific numbers of this rule are debatable, the chief point is that policy can be used most appropriately to reduce concentration -- political and economic.

One such policy action is the creation of stockpiles. Stockpiles have two main effects: they act as a deterrent to political or commercial restrictions, and they are a ready source of supply if disruptions should occur. The cost of building up stockpiles for the 22 classes of foreign products discussed in the study on dependency for precision-guided missile parts was nearly $15 million. The cost is the one-time investment for building an active inventory of parts, scaled to support production until new supplies would be forthcoming. Such a stockpile is not intended to be locked up in a bonded warehouse but to be continuously drawn on and replenished. The calculations of stockpile costs for the precision-guided missile parts took into account the unit costs of the items, the peacetime production rate and a surge rate, plus the length of time it would take to get an alternate source of supply into production (these times varied from two to 12 months). The estimated cost came to $12 million, with an additional $2.7 million to support surge production.[20] The authors noted with some surprise that the $15 million price tag for guarding against disruption seems rather small considering the roughly $6 billion spent annually for PGMs. Extrapolating from these rather optimistic figures, the cost of ensuring a full year's stock for every item would come to only about $30 million. The true economic cost of such a buffer is just the interest on the full amount, or roughly $3 million per year at a 10 percent rate of interest. Since a stockpile guarantees availability, in many ways it provides the greatest amount of insurance. Other policies, presumably, could yield similar benefits at lower cost.

The estimated $30 million stockpile cost for a year's supply, if distributed according to source by country, would show the United Kingdom in first place with $16.4 million, followed by Japan at $4.1 million and Germany at $1.4 million. A year's supply of integrated circuit components and FETs would come to $3.1 million.

Government need not operate the stockpile to gain the desired degree of self-sufficiency. Rather, through contractual penalties and explicit requirements, it could provide incentives to prime contractors to achieve continuity of production in the face of potential disruption. Contractors could choose, for example, to maintain sufficient inventories, secure multiple sources of supply, change the product design or, when considering the cost of insuring against vulnerability, the contractor may decide to buy from a domestic company that charges higher prices than foreign competitors. In any event, by giving incentives to its suppliers, the government can help to achieve more efficient solutions than if it simply dictated a specific approach.[21]

The policy of promoting the dispersion of sources addresses the problem of denied access to equipment and cutting-edge technologies -- whether for products themselves or the methods for producing them. With low concentration, discrimination against American buyers by state-of-the-art producers would be difficult to practice without collusion since the technologies or products would come from diverse sources. To encourage American capabilities in advanced defense technologies Mr. Moran recommends that the government grant top priority to funding research and development programs plus perhaps finance the early commercialization of projects with high defense payoffs but low commercial use. He also suggests that the government use various tax, subsidy and other levers in international negotiations to support the creation of new facilities on American soil. For example, the United States could allow companies from friendly countries to participate in government-funded research programs but require them to carry out the R&D in American facilities with subsequent production sited in the United States or a third country.[22] He specifically warns against government promotion of technologies with high commercial interest and expresses serious concern about protectionist measures that could encourage inefficiency and lower levels of innovation.

Defense analyst Jacques Gansler of The Analytic Sciences Corp. has recommended greater military use of off-the-shelf commercial items and less devotion to military specifications. Under this rationale, if the military could be weaned away from its MILSPEC orientation, the number of alternative sources would increase and the vulnerability potential decline. For example, the authors of several of the dependency studies question the military requirement for ceramic packages for integrated circuits. Commercial-use plastic packages should suffice for most applications except when high hermetic qualities are required -- and even then the special qualities of ceramics are open to dispute.[23]

On the political side the U.S. government may be able to negotiate agreements with its allies to provide supply priorities during emergencies and nondiscrimination in technology access during peacetime. The United States currently has a broad range of security agreements covering such behavior as intelligence sharing and overflight privileges and procedures. As supply networks become more globalized, it may be appropriate to address access issues in international relationships.

Several of the studies reviewed above considered the American dependency on production equipment, such as high-precision, multiple-axis, numerically controlled machine tools. This analysis was not discussed here because most of the production equipment dependencies would not lead to vulnerabilities if their supply were disrupted under the scenarios contemplated above. Only a large-scale, multiyear war with high rates of sustained production would put production equipment on the essential list. Given the length of time implied by this scenario, which most analysts now consider to be quite unlikely, finding alternative sources of parts or production equipment does not seem to be a critical problem.

A central point that emerges from a review of the evidence and the logic of dependence is that the diffusion of economic development and technological capabilities, when combined with the increased interdependence of the world's markets, almost guarantees that the United States will look increasingly to global sources for its defense technology, supplies and even final systems. It stretches credulity to think that any one country could be supreme in every sector, every process and every input. Even if the United States could achieve supremacy, economic analysis indicates that this country would be better off by specializing in those things it does best.

Conclusion

The problem of vulnerability in defense procurement is real, but its scale is limited. Policies to mitigate the possible effects of vulnerability can be managed at a reasonable cost without doing great damage to other objectives. Japan is a supplier of a small number of militarily critical items that can be dealt with at relatively low cost through the general application of broad policies.

Alexander Hamilton long ago recognized that a policy of general economic development was preferable to one that specifically favored defense suppliers. Defense needs, technologies and supply patterns can change in rather drastic fashion over the course of only a few years. Today's dependencies can become tomorrow's strengths -- and vice versa. Policies that lock in the future are best avoided.

For further information, contact **Arthur J. Alexander**.

Notes

[1]Cited in Arthur Harrison Cole (ed.), *Industrial and Commercial Correspondence of Alexander Hamilton* (New York, New York: Augustus M. Kelley Publishers, 1988), p. 247.

[2]Francis Narin and J. Davidson Frame, "The Growth of Japanese Science and Technology," *Science*, August 11, 1989, p. 602.

[3]Martin Libicki, Jack Nunn and Bill Taylor, *U.S. Industrial Base Dependence/Vulnerability: Phase 2 — Analysis* (Washington, D.C.: National Defense University, November 1987), p. 3.

[4]Theodore Moran, "The Globalization of America's Defense Industries: Managing the Threat of Foreign Dependence," *International Security*, XV, No. 1 (Summer 1990), pp. 57-59.

[5]Libicki, *op. cit.*, p. 31.

[6]Department of Commerce, Office of Industrial Resource Administration, *National Security Assessment of the Domestic and Foreign Subcontractor Base: A Study of Three U.S. Navy Weapon Systems* (Washington, D.C.: March 1992).

[7]Libicki, *op. cit.*

[8]Libicki, *op. cit.*, p. 117.

[9]Libicki, *op. cit.*, p. 123.

[10]Erland H. Heginbotham *et al.*, *Dependence of U.S. Defense Systems on Foreign Technologies* (Alexandria, Virginia: Institute for Defense Analyses, December 1990).

[11]*Ibid.*, p. S-1.

[12]*Ibid.*, p. 18.

[13]*Ibid.*, pp. B-III-9, B-III-10.

[14]*Ibid.*, p. B-IV-13.

[15]Department of Commerce, *op. cit.*, p. 8.

[16]Benjamin Zycher, Kenneth Solomon and Loren Yager, *An Adequate Insurance Approach to Critical Dependencies of the Department of Defense* (Santa Monica, California: Rand Corp., 1991), pp. 2-3.

[17]Moran, *op. cit.*, p. 67.

[18]Moran, *op. cit.*, p. 69.

[19]Moran, *op. cit.*, p. 85.

[20]Libicki, *op. cit.*, pp. 44-45.

[21]Libicki, *op. cit.*, and Zycher, *op. cit.*, make these points.

[22]Moran, *op. cit.*, p. 82.

[23]Libicki, *op. cit.*, p. 125.

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The views expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.